NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550/EO 3911 FINAL EXAM 12/00 Prof. Powers

- This exam is closed book and notes; 3 sheets of 8-1/2 x 11 paper (both sides) are allowed.
- There are four problems; each is equally weighted.
- Partial credit will be given; be sure to do some work on each problem.
- Be sure to include units in your answers.
- Please circle or underline your answers.
- Show *ALL* work.
- Write only your name on this sheet.
- Exams and course grades *should* be available outside the Optical Electronics Laboratory (Bu 224) on **Friday morning, 15 December**.
- If you want me to email your exam and course grades to you, send me an email request.
- Happy holidays and enjoy your break!

Course grade: _____

1		3	
2		4	
TOTAL			

Name: _____

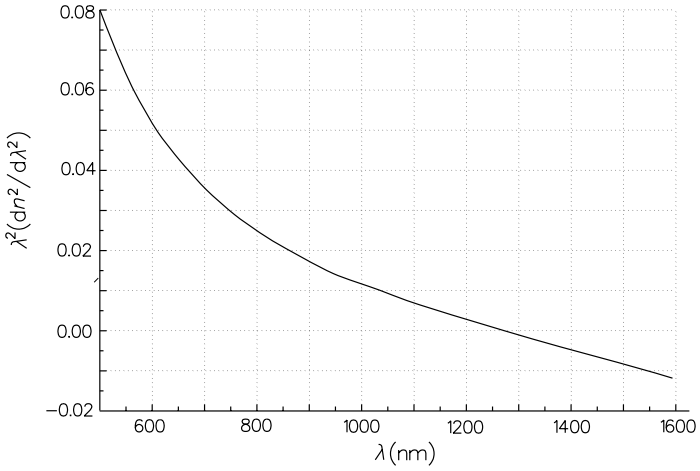

Figure 1: Fig. 3.8 of text

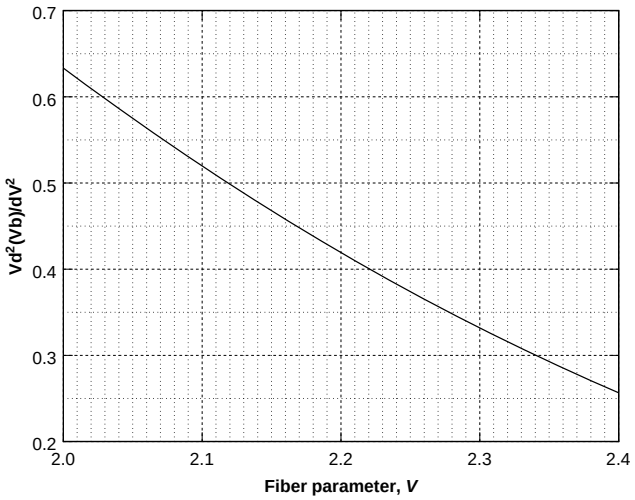

Figure 2: Fig. 3.10 of text

1. Please provide brief, concise answers to the following questions.

   (a) List one advantage that a graded-index multimode fiber has when compared to a step-index multimode fiber.

   (b) List one advantage that an APD detector has when compared with a pin-diode detector.

   (c) List four disadvantages that an APD detector has when compared with a pin-diode detector.

   (d) What is the primary advantage that an erbium-doped fiber amplifier has over a semiconductor optical amplifier?

   (e) In a lab discussion, a student asserts the measured optical power was "−21 dB". What is your response?

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2. Short problems.

   (a) A Fabry-Perot laser has a spectral linewidth of 3.0 nm and a frequency linewidth of 375 GHz. Find the wavelength of the laser.

   (b) A 2x2 coupler divides the power on any input evenly between the outputs (i.e., it is a 50:50 coupler). The coupler is assumed to be ideal and has no excess loss. One input has 3 dBμ of power; the other has 6 dBμ. Using the "dB method", calculate the power out of either output in μW and dBμ. (Note: The power out of each output is the same value.)

   (c) A 100/140 step-index multimode fiber operating at 1310 nm is known to have 1,270 modes. Find the NA of this fiber.

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3. Consider the fiber link shown in Fig. 3 operating at 1550 nm. Each splice has a loss of 0.5 dB. Each segment (loop) of fiber is 22 km long and the fiber loss is 0.30 dB/km at the operating wavelength. The power in the fiber at the transmitter is 600 μW. All pigtail fiber losses are negligible.

   (a) Using the "dB method", find the signal power at the receiver in dBm and in μW.

   (b) The receiver consists of a pin diode (quantum efficiency of 75%), a load 100-kΩ load resistor with a noise temperature of 350K, and a voltage amplifier with a voltage gain of 25 dB, a noise figure of 4.0, and an input resistance of 100 kΩ. Find the signal-to-noise ratio of the receiver. (You may assume that the thermal noise of the load resistor and the preamplifier are the dominant noise sources.)

   (c) Find the (minimum) BER of this link.

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4. Consider the fiber link shown in Fig. 4. The splice losses are each 0.7 dB. The amplifier parameters are given in the table below and the gain of the optical amplifier vs. the normalized input power is shown in Fig. 5a. The excess loss of the couplers from any input to any output

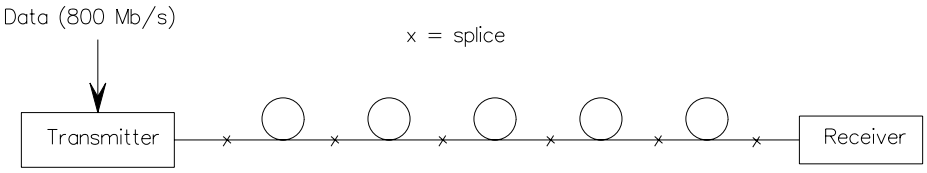

Figure 3: Fiber link for **Problem 3**.

is 1 dB. The reflectivity of the Bragg grating device is shown in Fig. 5b. All fiber pigtail losses are negligible.

One of the lasers (operating at 1300 nm) is transmitting digital data at 50 Mb/s. The power in a logical "1" at position A, P_A, is measured as 100 μW.

(a) Using the "dB method", calculate the power, P_B, that results from light being reflected by the fiber grating.

(b) A receiver, consisting of a pin diode (quantum efficiency of 50%) and a 50-Ω load resistor is placed at the location "B". Using the definition of signal-to-noise ratio, calculate the signal-to-noise ratio for this receiver when a logical "1" is received, assuming that the signal is the light reflected by the grating. You may also assume that the noise is dominated by the noise associated with two noise sources that depend on P_{ASE}.

Amplifier parameters

Parameter	Value
Gain	See Figure 5a.
n_{sp}	2
P_{sat}	-40 dBm
$\Delta\nu_{\text{amp}}$	3.74 THz (3,740 GHz)
B_o	1.5 nm

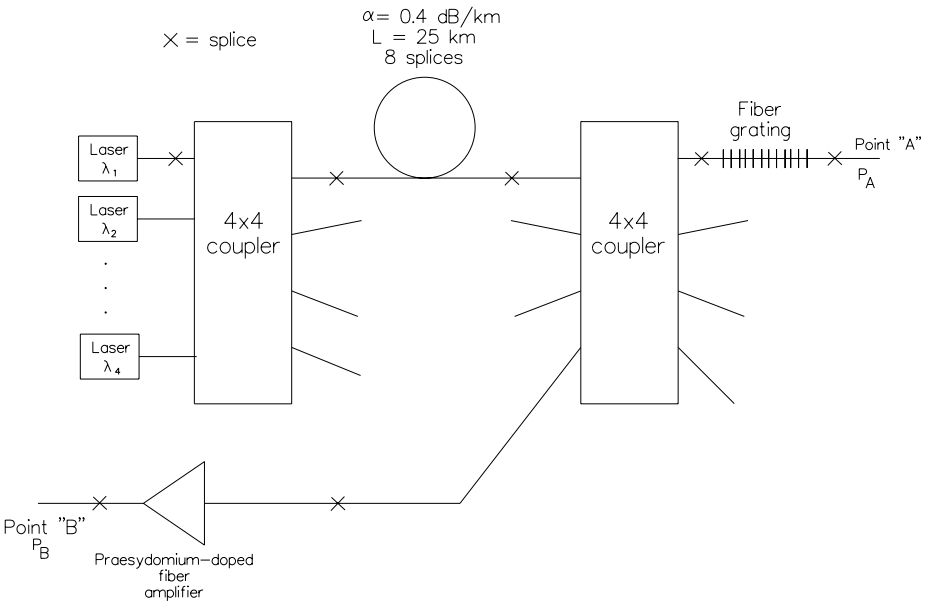

Figure 4: Component connection for **Problem 4**.

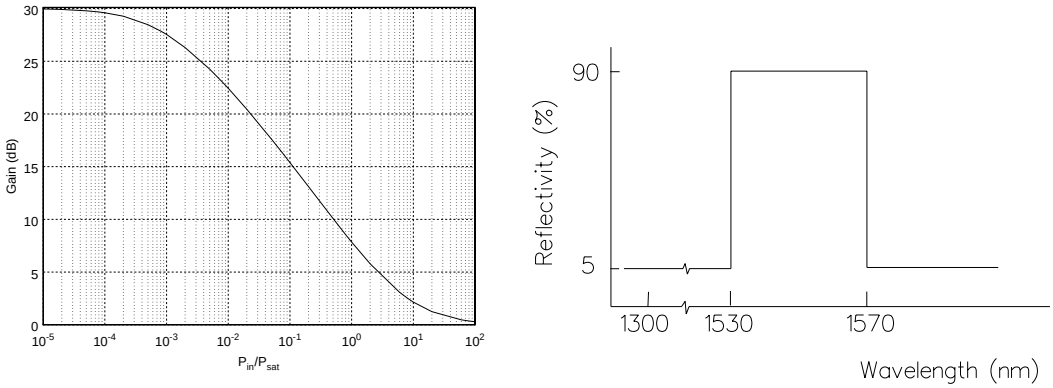

Figure 5: **Problem 4** data: (a) Gain vs. normalized input power of fiber amplifier and (b) Reflectivity vs. wavelength for fiber grating (idealized).